A peer-reviewed open-access journal
NeoBiota
Advancing research on alien species and biological invasions

NeoBiota 102: 313–329 (2025)
DOI: 10.3897/neobiota.102.143330

Research Article

Effectiveness of legislative tools to stop biological invasions: freshwater turtles' invasion in Europe as a study case

João Rato[1,2,3], Pedro Brandão[1,2,3], Mafalda Gama[1,2,3], Filipe Banha[1,2,3], Pedro Anastácio[1,2,4]

1 *MARE – Marine and Environmental Sciences Centre, Évora, Portugal*
2 *ARNET – Aquatic Research Network, Évora, Portugal*
3 *IIFA - Institute for Research and Advanced Training, University of Évora, Palácio do Vimioso, Largo Marquês de Marialva, 7002 - 554, Évora, Portugal*
4 *Department of Landscape, Environment and Planning, University of Évora, Rua Romão Ramalho, 59, Évora, Portugal*

Corresponding author: João Rato (d55794@alunos.uevora.pt)

Abstract

Invasive species pose significant threats to biodiversity, human health, and economic systems. Freshwater turtles are popular as pets, but when released or allowed to escape into the wild, they can become invasive. A prominent example is the red-eared slider *Trachemys scripta*, which is recognized as a globally invasive species. Legislative tools, such as the European Union Regulation 1143/2014 on the prevention and management of invasive alien species, aim to combat these threats. This framework includes the implementation of Commission Implementing Regulation 1141/2016, which banned the trade of listed invasive species, including *T. scripta*. This study evaluates the effectiveness of Regulation 1143/2014 on *T. scripta* invasion and its consequences on other freshwater turtle invasions, using data from the CITES database and the GBIF platform. While *T. scripta* imports into the EU ceased after 2016, the species continues to establish and expand in the wild. This suggests that the trade ban had minimal impact on already established populations, highlighting the need for additional measures to reduce and control its spread. Simultaneously, imports and records of other freshwater turtle species have risen, indicating a shift in trade dynamics. These species are increasingly being introduced, potentially exacerbating the biological invasion problem. Despite limitations inherent to CITES and GBIF data, our findings suggest that the current European legislation has not been effective in mitigating *T. scripta* invasions and may have unintentionally contributed to the introduction of other invasive turtles. We recommend that the European Union develop invasive species lists tailored to each biogeographic regions of Europe to enhance the effectiveness of legislation.

Key words: Exotic species, management, pond turtle, regulations, terrapin

OPEN ACCESS

Academic editor:
Tammy Robinson-Smythe
Received: 2 December 2024
Accepted: 9 April 2025
Published: 7 October 2025

Citation: Rato J, Brandão P, Gama M, Banha F, Anastácio P (2025) Effectiveness of legislative tools to stop biological invasions: freshwater turtles' invasion in Europe as a study case. In: Anastácio P, Ribeiro F, Chainho P (Eds) Invasions in Aquatic Systems. NeoBiota 102: 313–329. https://doi.org/10.3897/neobiota.102.143330

Copyright: © João Rato et al.
This is an open access article distributed under terms of the Creative Commons Attribution License (Attribution 4.0 International – CC BY 4.0).

Introduction

The global trade of exotic animals, including both international and domestic trade, is a very lucrative business which, accounting only for the legal trade, provides revenues of millions of dollars (Lockwood et al. 2019). Globally, some of the most traded groups are birds (orders Psittaciformes and Passeriformes) and reptiles (orders Squamata and Testudines) (Bush et al. 2014). Nevertheless, domestic markets, non-traditional markets (such as websites and social media pages), and illegal markets remain undocumented or poorly documented, which makes global assessments of trade difficult (Lockwood et al. 2019). On the other hand, "legal"

international trade is well documented. For example, the international trade of exotic species that are threatened is regulated by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Depending on its threatened status, a species trade may only be authorised under special circumstances (Appendix I, CITES 2025), may be subjected to strict rules not to endanger the species (Appendix II, CITES 2025) or may even have special rules for specific parties (Appendix III, CITES 2025). Convention parties are obliged to report imports and exports of the species included in the CITES appendices, these are gathered in an international database (https://trade.cites.org/). However, many species are not regulated by CITES because they are not considered threatened and thus remain freely traded (Bush et al. 2014). The need to document species trade is not only related to identifying and regulating the trade of endangered species but also to identifying and preventing the introduction of exotic species (Gippet and Bertelsmeier 2021). The commercial success of a species can increase its invasive potential, as the most traded species are also the ones with the potential of being most introduced outside their native range (Gippet and Bertelsmeier 2021).

Like many exotic animals kept as pets, freshwater turtles (FTs) are often released to the wild when they get bigger and older (Banha et al. 2019). As a result, FTs have become invasive worldwide and, in some cases, with great success, as the red-eared slider (*Trachemys scripta* THUNBERG, 1792) (European Environment Agency 2012). This species has been introduced to virtually every continent, mainly through the pet market, and has severe impacts on biodiversity and human health (European Environment Agency 2012). At the biodiversity level, *T. scripta* may impact native FTs, by competing for food and thermoregulation sites, displaying aggressive behaviour, and/or disease transmission (Polo-Cavia et al. 2014; Rato et al. 2024b). Due to their opportunistic feeding behaviour and their dietary ontogenic shift, *T. scripta* feeds on a variety of animal and plant species, which has implications for aquatic communities (Pérez-Santigosa et al. 2011; European Environment Agency 2012). Regarding human health, *T. scripta* is a well-known reservoir of *Salmonella* spp., which has caused several pet turtle-associated salmonellosis outbreaks in the USA (Basler et al. 2015). These turtles may also harbour other zoonotic disease agents, like *Leptospira* sp. and *Chlamydia* spp., among others (Mitura et al. 2017; Bonacina et al. 2021).

To reduce the impacts and minimise introduction risk of these species, several actions may be taken such as environmental education, prevention, control and eradication of established populations. One of the possible actions is the creation of legislation to prevent the introduction of non-native and invasive species. Such legislation, typically including species' blacklists, may prohibit the trade, the reproduction, and the maintenance under captivity of certain non-native and invasive species that are particularly damaging to the ecosystems, or in some cases, that might be disease vectors (Simberloff 2006; Zamora-Marín et al. 2023). However, these blacklists (1) often include some, but not all, of the already introduced species in an area/country, (2) do not prevent the spread of established species or the substitution of their trade by similar species, and (3) do not involve any financial support for their implementation (Simberloff 2006; Oficialdegui et al. 2023; Zamora-Marín et al. 2023). To complement the blacklists, some countries have created whitelists, i.e. lists of authorized species to trade, which may be associated with a risk analysis (Simberloff 2006). In the European Union, in 1996 the Council Regulation (EC) 338/97, which regulated the trade of some exotic species was

created, but only included one FT, *T. scripta*. However, the implementation of this regulation alone was insufficient to halt the spread of invasive species. To address this, a subsequent regulation, Regulation 1143/2014, was introduced. It includes a list of non-native species of Union Concern whose trade is prohibited by implementing regulation 1141/2016. However, this regulation initially listed only one freshwater turtle (FT). It is worth noting that the list of species of Union concern may differ from those established at the national level, i.e. the lists of species of national concern as per Article 12 of Regulation 1143/2014. For example, the Portuguese blacklist includes five non-native turtles (*Macrochelys temminckii*, *Chelydra serpentina*, *Pseudemys* spp., *Graptemys* spp. and *Trachemys* spp.) while the Spanish blacklist includes three non-native freshwater turtles (*Chrysemys picta*, *Pseudemys peninsularis* and *Trachemys scripta*) (Decreto-Lei n.o. 92/2019, 2019; Real Decreto 216/2019, 2019).

The traditional field monitoring of non-native and invasive species may be extremely difficult and time-consuming, and some projects and studies are starting to incorporate data from citizen science projects (Johnson et al. 2020). Although it has some constraints, citizen science may be an effective way to gather long-term and large amounts of species distribution data (Johnson et al. 2020; Larson et al. 2020). For invasive species monitoring, it may be particularly important to record the first detection of a species, to update the distribution of non-native/invasive species and to use distribution data to predict future distribution ranges (Johnson et al. 2020). Some projects are species-specific (Johnson et al. 2020; Larson et al. 2020), which may limit the detection of different non-native species. The Global Biodiversity Information Facility (GBIF) is an international database that compiles data information from multiple data sources, including from several citizen science projects, for many of the world's species. This open-access database may be used to monitor non-native and invasive species (Ivanova and Shashkov 2021).

To evaluate the impact of legislation in preventing and mitigating the invasive species introductions associated with the pet market, we used the freshwater turtle's invasion in Europe as a case study. Namely, we focused on the effectiveness of the 1143/2014 European Union regulation on *T. scripta* invasion, included in the implementing regulation 1141/2016, comparing EU with non-EU countries. We analyzed *T. scripta* number of imports and records in the wild for all European countries, both EU members and non-EU members. Similarly, we also gathered imports and records in the wild, for other species of FTs. We expected to find a reduction in the imports of *T. scripta* along with a stabilization or reduction of *T. scripta* records, potentially accompanied by an increase in the imports and records of other FTs, particularly in EU member states.

Methods

Data acquisition and datasets

Importation data was acquired from the CITES database on February 2nd 2024. We chose to only use CITES listed species because this is the longest running import dataset, using data from 1998 until 2022. Other data on international trade of FTs is scarce. We started in 1998 because the mandatory report of CITES listed species for EU countries only started in June 1997 (Council Regulation (EC) 338/97 1996). *Trachemys scripta* is not listed as an endangered species by any of

the appendices of CITES; however, due to its invasive status, it was added to the transcription of CITES to the EU legislation, and therefore, this species' importations are also reported and added to the CITES database. We did not incorporate any data or estimates from domestic and illegal trade of non-native freshwater turtles. From the CITES dataset, we only retrieved data from European countries and excluded any imports of dead specimens, animal parts, and eggs, leaving only live juvenile and adult turtles. All importation purposes, from pet to research, were included in the retrieved dataset. The total number of turtles imported for each purpose can be consulted in Suppl. material 1: table S1. To standardize all importation data, imports reported in kg were divided by the mean reported species weight to get the number of live specimens. We grouped all imports of other FTs in a single variable.

On February 15th 2024, we retrieved from GBIF all European observation records for all the CITES listed freshwater turtle species for each year for the same period (1998–2022). We excluded data that came from fossil records, preserved specimens, material citations, and sample citations, leaving only live specimens' observations. Like for the CITES dataset, we separated *T. scripta* observations and grouped the remaining FTs' observations into a single variable, for each year and country. The two datasets were then joined by the corresponding year and country.

Statistical analysis

For the modeling approach, the spatio-temporal variation of import and presence in the wild data for freshwater turtles was explored using linear mixed models (LMMs). LMMs were used because traditional statistical regression methods are not adequate when variables have non-linear relationships, as is expected for most biological contexts. LMMs have also been widely used for modeling data on invasive species with a wide distribution and spatial/temporal dependence, taking into account random factors (Thiele and Markussen 2012; Costa 2014). For each of the models, the response variables were modelled using Period (before vs after the regulation 1143/2014), EU membership, Country population, *Trachemys scripta* imports and records and other FTs' imports and records (i.e. fixed effects). The GBIF records were aggregated as the total number of *T. scripta* records per country per year. Similarly, for other FTs, the GBIF records were calculated as the total number of non-*T. scripta* FT records per country per year. Year, GDP, Country area and Country were treated as random factors to consider possible variations in terms of the legislation enforced. For the records models we also used the number of GBIF records of testudines species in Europe as random factor. The use of random factors allowed to account for the variability not explained by the fixed effects. For the variable Period we considered two periods: Before 2016 and After 2016. We chose 2016 because it was the year of publication of implementing regulation 1141/2016, which classified *T. scripta* as invasive species of Union concern and prohibited its trade in the EU. For each year, we classified the countries as EU or non-EU members according to their date of entry to the EU; this resulted in a different number of countries in each year for both countries' groups (Suppl. material 1: table S2). To check for multicollinearity and redundancy of variables, following Fielding and Haworth (1995), a Spearman correlation analysis was conducted. Only Year and number of CITES listed species, as well as Country and Country area showed a high correlation coefficient ($r > 0.9$), and therefore we excluded the

number of listed CITES species and Country area from our analysis (Suppl. material 1: fig. S1). The best model was obtained by considering models with different variable combinations and selecting the best fit model using Akaike information criterion (AIC), with the most parsimonious models presenting the smallest AIC (goodness-of-fit measure) (Vrieze 2012). Post-hoc comparisons after LMM were performed to estimate pairwise differences between the categorical variables using Tukey-HSD tests including *p*-value corrections for multiple comparisons, summarized in Suppl. material 2. A statistical significance level of 0.05 was considered in all test procedures. Statistical analyses were performed within the R Software (Version 1.1.463) (Posit team. 2022) using the "mgcv" (Wood 2011), "ggplot2" (Wickham 2016) and "lme4" (Bates et al. 2015) packages.

The limitations of using the CITES database and GBIF records to assess the effectiveness of Regulation 1143/2014, as well as their implications for other exotic freshwater turtles, are discussed in Suppl. material 3.

Results

The top 10 most traded species in European countries according to CITES and the top 10 species with most records on GBIF, excluding *Trachemys scripta*, are identified in Table 1. Five species – *Graptemys pseudogeographica*, *Mauremys reevesii*, *Mauremys sinensis*, *Graptemys ouachitensis*, and *Pelodiscus sinensis* – rank among the most frequently traded and recorded species.

The best *Trachemys scripta* imports model was composed by period, EU membership and the interaction between period and EU membership, with the interaction presenting the only significant result (p-value = 0.0287, Table 2). Tukey test results showed significant differences between *T. scripta* imports in EU and non-EU countries before the legislation and between the period before and after the legislation for EU countries (Suppl. material 2, but also visible in Fig. 1A). Data on annual imports show that *T. scripta* imports start to decrease from 1998 until 2000 when they started to stabilize at low numbers and completely stopped in 2016. By opposition other FTs' imports remained stable until 2004 when they started to increase, with a peak in 2018 for EU countries and a peak in 2021 for non-EU countries (Suppl. material 1: fig. S2), despite of the influence of *T. scripta* imports on the other FTs' imports being non-significant (Table 2). The main European importers were Spain, Portugal, and Belgium (Fig. 2A).

For *T. scripta* records the best model was the one that incorporated period and EU membership. However, none of these were significant in their own right (Table 2). *T. scripta* records increased since 1998 for both country groups, but with a slight stabilization in the later years for non-EU countries. This differs from *T. scripta* imports, which had a huge number of importations between 1998 and 2000 and stopped after 2016 (Fig. 1A, B; Suppl. material 1: fig. S2). Overall, the increase in *T. scripta* records was correlated with an increase in all testudines records in Europe (r^2= 0.9, Suppl. material 1: figs S1, S3). When looking at the difference between the EU members and non-members, *T. scripta* records had increased in both countries' groups, although the total number of records was different, being higher in EU countries (Fig. 1A, B). The countries with the largest number of records per km^2 were Belgium, The Netherlands, Luxembourg, and Spain, which all belong to the EU (Fig. 2B). Overall, *T. scripta* records were higher after 2016, compared to the previous period, for EU countries (Table 2, Fig. 1B).

Table 1. Top 10 most imported and top 10 most recorded freshwater turtles from 1998 to 2022 for all Europe (combined EU and Non-EU countries), apart from *Trachemys scripta*, ranked by decreasing order. Species included in both lists are in bold.

Most traded species on CITES		Most recorded species on GBIF	
Family	**Species**	**Family**	**Species**
Emydidae	***Graptemys pseudogeographica***	Emydidae	***Graptemys pseudogeographica***
Geoemydidae	***Mauremys reevesii***	Emydidae	*Pseudemys concinna*
Geoemydidae	***Mauremys sinensis***	Chelydridae	*Chelydra serpentina*
Emydidae	***Graptemys ouachitensis***	Emydidae	*Pseudemys nelsoni*
Pelomedusidae	*Pelomedusa subrufa*	Emydidae	***Graptemys ouachitensis***
Trionychidae	***Pelodiscus sinensis***	Geoemydidae	***Mauremys sinensis***
Pelomedusidae	*Pelusios niger*	Emydidae	*Chrysemys picta*
Emydidae	*Graptemys versa*	Geoemydidae	***Mauremys reevesii***
Podocnemididae	*Podocnemis unifilis*	Emydidae	*Pseudemys rubriventris*
Pelomedusidae	*Pelusios castaneus*	Trionychidae	***Pelodiscus sinensis***

Table 2. Results of the selected LMM to explain variation on the imports and records of *Trachemys scripta* and other FTs per squared kilometre and species. All variables included in the models were significant.

Model (n = 2070)	Model term	Fixed effects			Random effects	
		Estimate	**SE**	**P-value**	**Variance**	**SD**
Trachemys scripta imports	Period: Before 2016	-11.84	100.225	0.9059	–	–
	EU: Yes	1.069	68.9202	0.9876	–	–
	Period × EU	**178.303**	**81.5145**	**0.0287**	–	–
	(1|Year)	–	–	–	33272	5168
	(1|Country)	–	–	–	3780	182.41
Trachemys scripta records	Period: Before 2016	-0.7396	0.8611	0.3903	–	–
	EU: Yes	-0.5924	1.3871	0.6693	–	–
	(1|All records)	–	–	–	122579.46	350.114
	(1|Year)	–	–	–	0.000e+00	0.0000
	(1|Country)	–	–	–	118.40	10.881
	(1|GDP)	–	–	–	0.000e+00	0.0000
Other FTs' imports	Period: Before 2016	3.293e+02	2.080e+03	9.001e-01	–	–
	EU: Yes	**1.088e+04**	**3.131e+03**	**5.216e-04**	–	–
	Period x EU	**-1.138e+04**	**2.641e+03**	**1.631e-05**	–	–
	Imports *Trachemys scripta*	-1.615e+00	9.501e-01	8.904e-02	–	–
	(1|Year)	–	–	–	3412347	0.08907
	(1|Country)	–	–	–	182548370	1847.3
	(1|GDP)	–	–	–	185035	430.2
Other FTs' records	**Imports other**	**7.735e-06**	**1.841e-06**	**2.66e-05**	–	–
	(1| All records)	–	–	–	2.024e+02	14.22653
	(1|Year)	–	–	–	3.159e-03	0.05621
	(1|Country)	–	–	–	0.000e+00	0.00000
	(1|GDP)	–	–	–	6.304e-04	0.02511

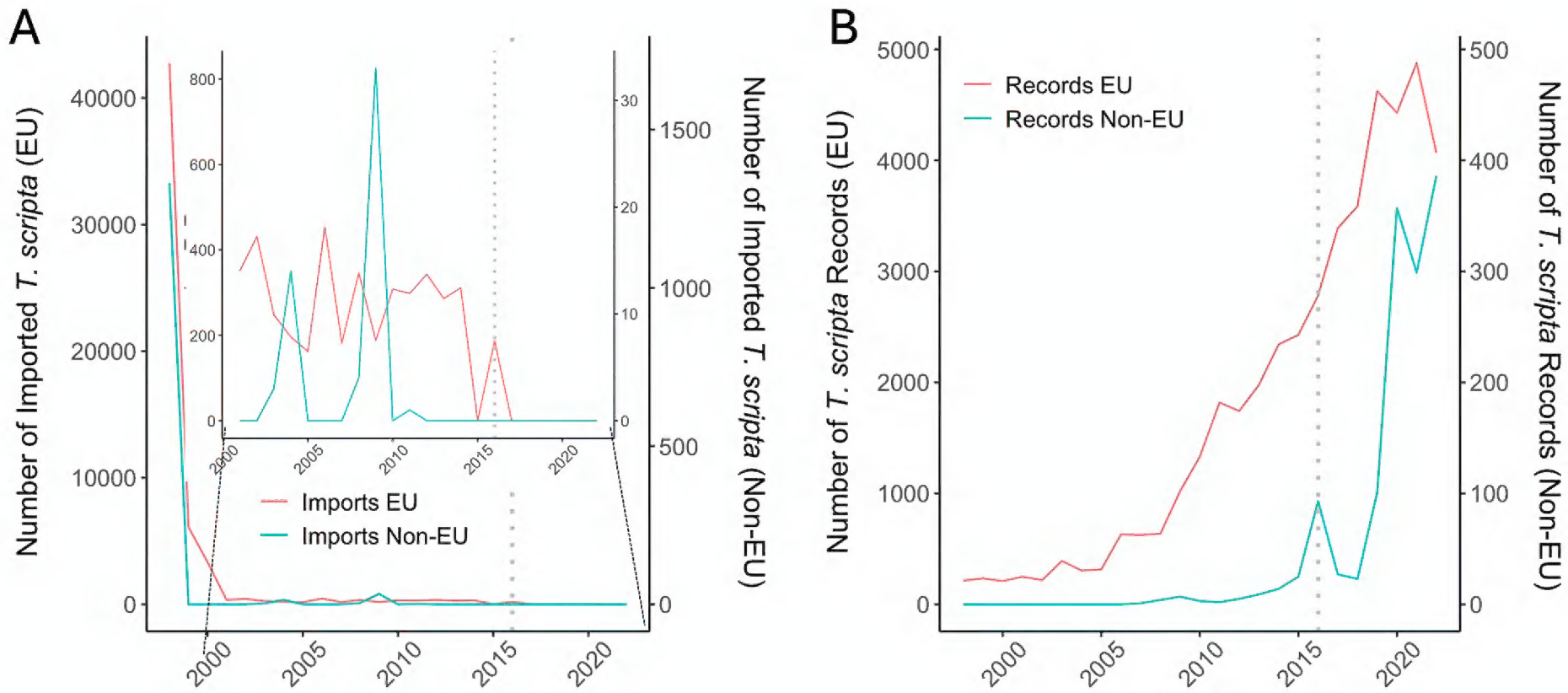

Figure 1. *Trachemys scripta* annual variation of imports and records in nature, between 1998 and 2022. Red line- EU member states. Blue line- non-EU countries **A** total imports by year in CITES database **B** total records in GBIF per year.

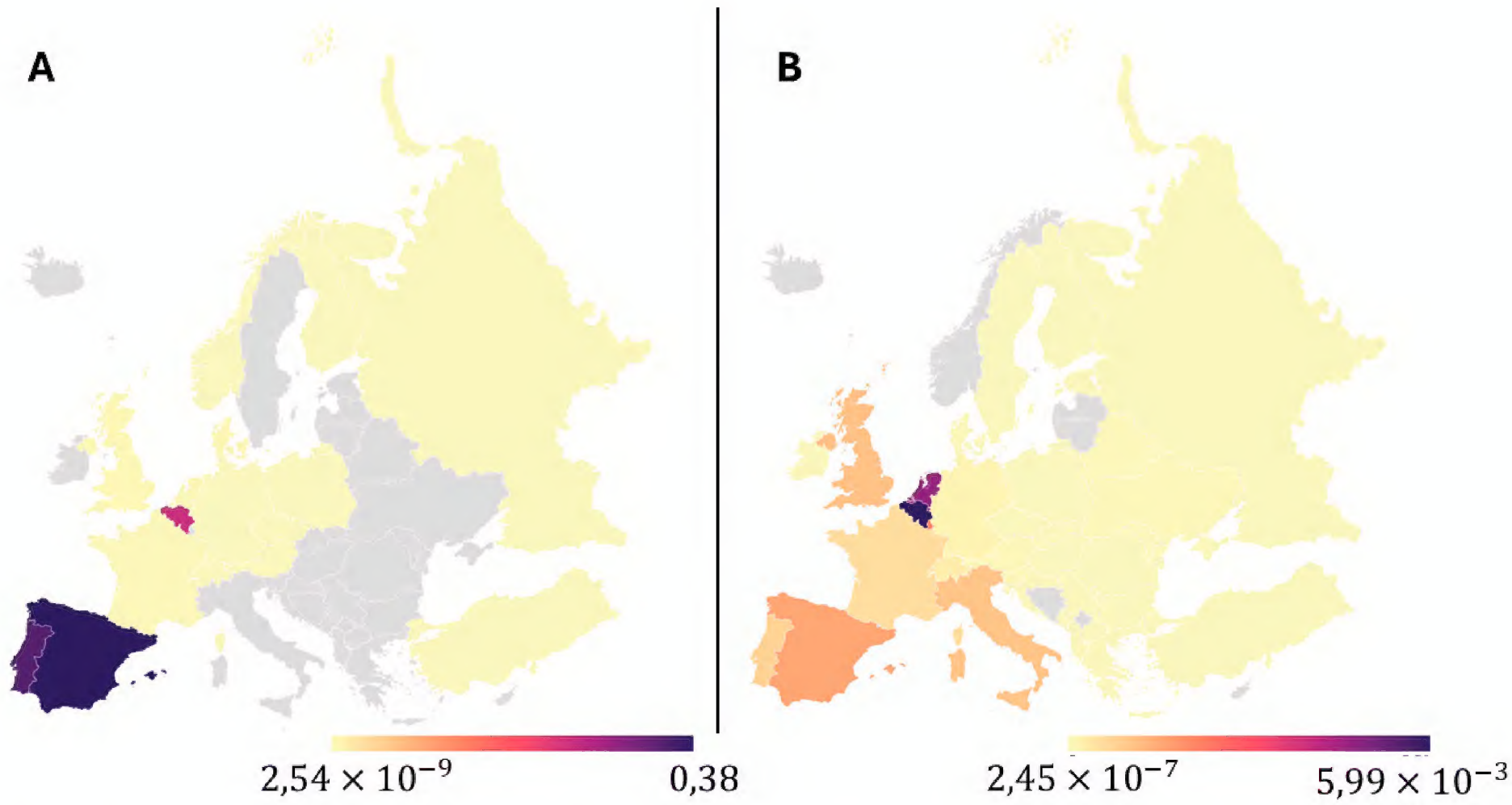

Figure 2. *Trachemys scripta* imports and records in Europe (both EU and Non-EU countries), combined between 1998 and 2022 **A** total imports per country per square kilometre **B** total records per country per square kilometre. Increasing number of imports (**A**) and (**B**) from lighter to darker colours. Grey colour corresponds to absent data.

The best model for other FTs' imports included Period, *T. scripta* imports, EU membership and the interaction between the period and EU membership. For this model only *T. scripta* imports and Period were non-significant (p-value = 0.0967). The import of other FTs reached its maximum in 2019 (Fig. 3A; Suppl. material 1: fig. S2). Before 2005, the imports of other FTs were very low. Like in the other models, the number of imported turtles was higher in EU countries (Table 2 and

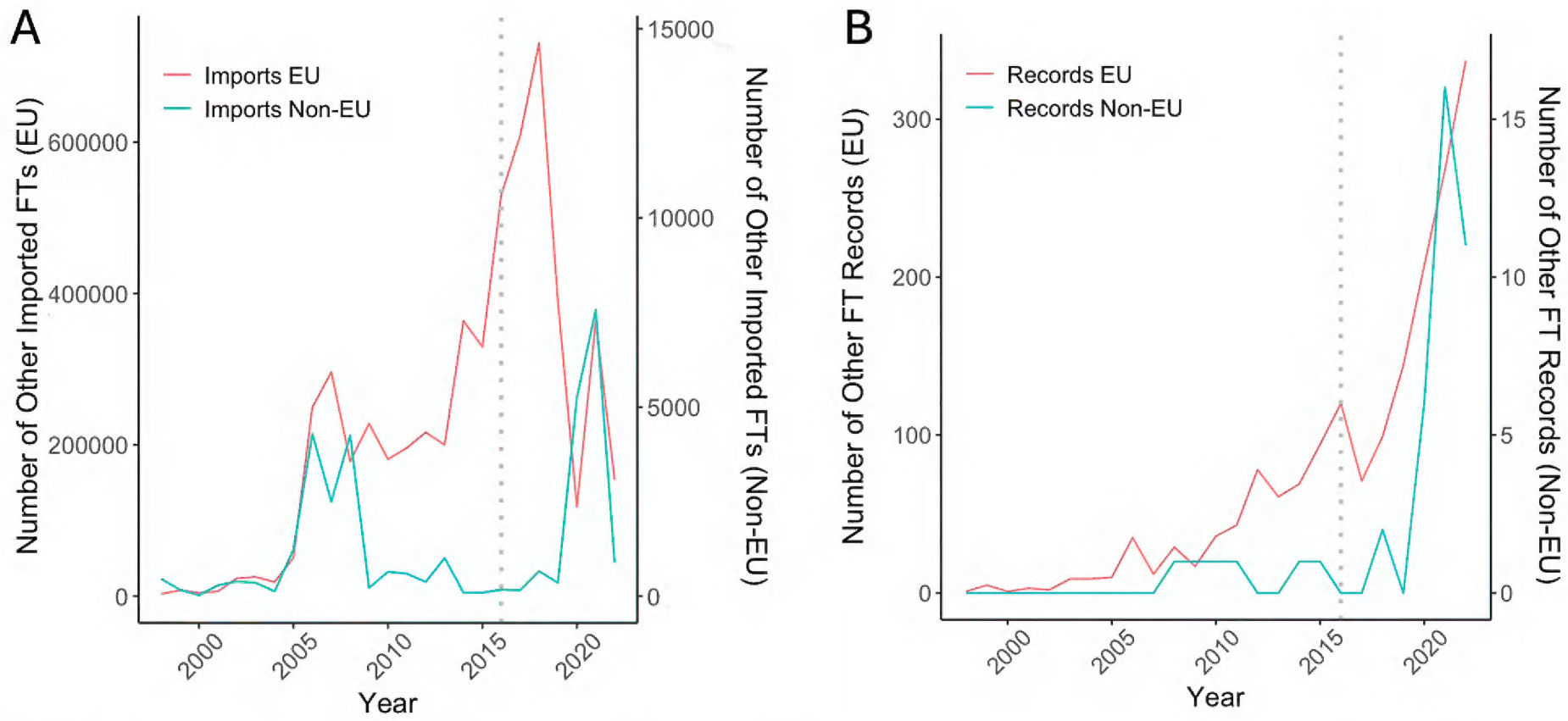

Figure 3. Other non-*Trachemys scripta* freshwater turtles' annual variation of imports and of records in nature. Red line- EU member states. Blue line- non-EU countries **A** total imports by year in the CITES database **B** total records in GBIF per year.

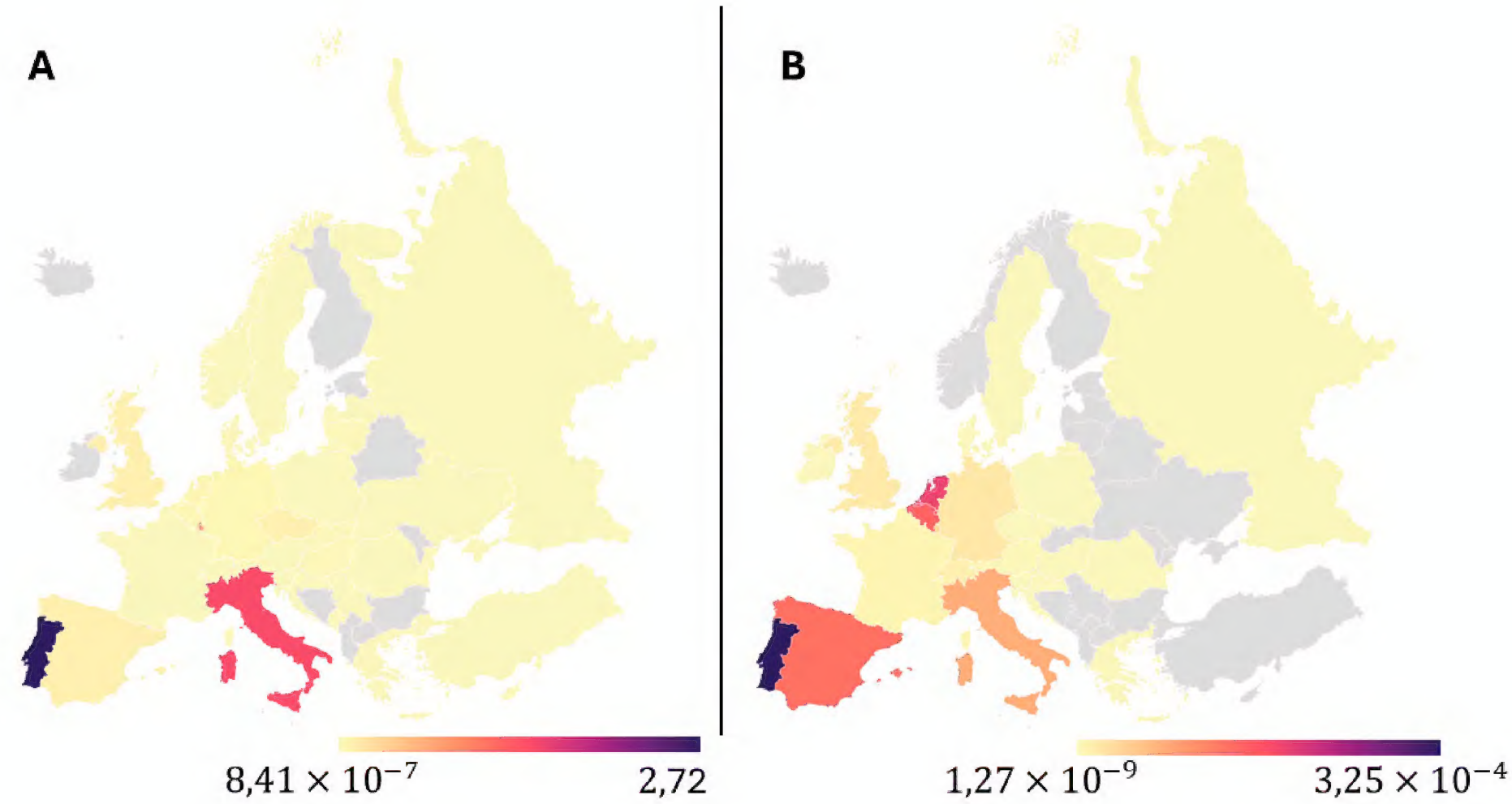

Figure 4. Other non-*Trachemys scripta* freshwater turtle imports and records in Europe (both EU and Non-EU countries), combined between 1998 and 2022 **A** total imports per country, per square kilometre, per CITES listed species **B** total records per country, per square kilometre. Increasing number of imports (**A**) and (**B**) from lighter to darker colours. Grey colour corresponds to absent data.

Fig. 4A). The countries with the largest number of imports were Portugal, Italy and Luxembourg (Fig. 4A). The Tukey test was significant for all interactions except for non-EU countries between, before and after 2016 (Suppl. material 2).

Finally, regarding other FTs' records, the best model only included the variable of other FTs' imports, and it was significant (p-value = 2.66e-05, Table 2). The number of other FTs' records was small, with a substantial increase from 2005 onwards (Fig. 3B, Suppl. material 1: fig. S4). The countries with the largest number

of records all belong to the EU, namely Portugal, Spain, The Netherlands, and Belgium (Fig. 4B). The remaining countries only have occasional records by square kilometer (Fig. 4B).

Discussion

From our results, we can conclude that, despite the legislation leading to a reduction in *T. scripta* imports, the records of this species did not decrease in the wild. On the other hand, other freshwater turtles (FT) imports increased with the legislation implementation, and these imports could at least partially explain the increase in records of other FTs in the wild.

Imports of *T. scripta* ceased entirely with the implementing Regulation 1141/2016, which may lead to a reduction of new introductions of this species. Additionally, propagule pressure is also important at the post-establishment stages of invasion (Colautti and MacIsaac 2004), as it promotes the arrival of new propagules from the outside of the established populations. Although international trade was stopped, the same might not have happened with the in-country and illegal trade. This was also found for other taxonomic groups, for instance, in the Australian ornamental fish industry, several black-listed species continue to be traded, particularly through e-commerce (Millington et al. 2022). This might be reduced by applying strong control to the internal trade of pet species, and not focusing only on international trade (Millington et al. 2022). It is relevant to note here that the mean imports of *T. scripta* in non-EU countries are very low compared to EU countries, which might be related to the low GPD of non-EU countries (Evans et al. 2018).

Even while *T. scripta* imports decreased between 1998 and 2000 and reached a relatively low level after that year, records did not follow the same trend. After 2003, *T. scripta* records were continuously increasing, and in 2018, there was a large increase in the number of records that was maintained high until 2022. This aligns with the general trend observed in the records of all turtle species in Europe, where a mean of 40% (ranging from 17% to 64%) of annual records are attributed to *T. scripta*. In our statistical analysis we included, as a random factor, the records of all turtle species in Europe to account for the increasing use of citizen science platforms over the years, and so our results already consider that effect. Despite not being statistically significant, the variable *T. scripta* imports follows the opposite trend of the *T. scripta* records. This is an indication that the imports' reduction did not affect the records in the wild, and therefore a blacklist alone has not stopped the invasion of *T. scripta.* The same happened with *T. scripta* records after the national legislation implementation in Spain (Maceda-Veiga et al. 2019). Although legislation implementation increased the voluntary surrendering of animals to the competent authorities and the confiscation of prohibited species, the number of wild/feral individuals remained unchanged (Maceda-Veiga et al. 2019). The EU regulation 1143/2014 also includes other measures to control and eradicate invasive species, however, since the number of *T. scripta* is increasing, the EU regulation, as it is, might be ineffective to stop the *T. scripta* invasion.

There are several explanations for the increase in *T. scripta* records, instead of its reduction. Firstly, the measures predicted in the 1143/2014 regulation are either not being applied by the EU member states or these measures, despite being applied, are not sufficient to stop *T. scripta* invasion. Additionally, due to the fact that *Trachemys scripta* is a long-lived species, the impact of some control measures (like egg removal) might not be evident yet. Secondly, *T. scripta* was already present in

nature in several European countries before the regulation's implementation (Semenov 2010). Which means that wild populations already existed, before this regulation. Naturally, these wild populations may reproduce, increasing turtles' numbers. There are several reports of *T. scripta* reproduction in Europe (Perez-Santigosa et al. 2008; Liuzzo et al. 2020). This species also has a high dispersion capability, and can easily colonize new habitats (Semenov 2010). Therefore, the dispersion of growing populations may cause an increase in records, despite the decrease in imports. Thirdly, despite the decrease in reported imports, illegal trade may still occur (García-Díaz et al. 2017; Kopecký et al. 2019). Illegal trade has been increasing and can occur between countries or within a country (Easter et al. 2023). Nonetheless it remains very difficult to quantify illegal wildlife trade due to the lack of data (Easter et al. 2023). Additionally, social media and e-commerce have added a new dimension to the illegal pet market. Most of the time, the turtle species found on social media and online stores, are not commonly found in physical stores, and some of them are illegal to sell (Sung et al. 2021). Fourthly, although the EU regulation 1143/2014, and consequently the implementing regulation 1141/2016, also prohibits breeding of the listed species, several private owners still breed *T. scripta*. Environmental education and awareness programs should increase public compliance with this European regulation, so pet turtles may be delivered to the competent authorities rather than being kept or released. Lastly, due to their high mobility (Semenov 2010) *T. scripta* may move from non-EU countries to neighboring EU countries if they share any international aquatic border or if they have aquatic ecosystems near each other. Taking into account all of the above, we consider that the EU legislation, particularly EU regulation 1143/2014 and its implementing regulation 1141/2016, was not effective in stopping the expansion of an already established invasive species, *T. scripta*, despite its impact on the imports of this species. From our perspective, this situation arises because, in many cases, the European Union has only implemented legislative measures after species have become established and widespread, with a few notable exceptions. This reactive approach should be complemented by the proactive inclusion of species that have the potential to become invasive and/or cause significant ecological or economic impacts upon introduction (Maceda-Veiga et al. 2019). Currently, EU legislation omits numerous introduced or potentially introduced species – many of which are classified as high-impact (Oficialdegui et al. 2023). As a result, key measures outlined in Regulation 1143/2014 cannot be applied to these species. The Regulation does provide mechanisms for addressing invasive species that are of national, rather than Union-wide, concern by allowing their inclusion in national invasive species lists. It also permits the activation of emergency measures for newly introduced species not yet listed as Species of Union Concern. However, the responsibility for establishing national lists lies with individual Member States. For instance, in the Iberian Peninsula, Oficialdegui et al. (2023) found that many introduced aquatic species are absent from both the Portuguese and Spanish invasive species lists.

Potentially in response to the ban on *T. scripta* imports, the importation of other freshwater turtles peaked in 2016. Our results suggest that implementing regulation 1141/2016 induced a sudden increase in other FTs' demand but only in EU countries. EU countries had higher imports of other FTs, after the legislation implementation, when compared with EU countries before the legislation and with non-Eu countries after the legislation. This means that the prohibition of highly demanded pet turtles, resulted in the search for new, but similar, pet turtles.

In our study, Emydidae was the most traded family, even when *T. scripta* imports were excluded, with many of those species being from North America. Actually, a large portion of the imported species may have similar ecological requirements to *T. scripta*, which has high habitat suitability for Europe (Banha et al. 2017; Nori et al. 2017). The substitution of a prohibited species for other similar species is very common. For instance, the ban of international trade of tiger products led to an increase in the trade of lion products (Macdonald et al. 2021). This also impacts natural populations because in several cases animals are retrieved from wild populations, leading to population decline, which often is not solved by wildlife farming (Macdonald et al. 2021). Traded species are often a result of preferences for the species behavioral and morphological characteristics and consumers socio-demographic status (Pienaar and Sturgeon 2024). Nevertheless, education seems to negatively affect turtle purchase (Azevedo et al. 2021; Pienaar and Sturgeon 2024), and may be a better way than simply reducing turtle importation, since this clearly reduces the turtles' release into the wild.

Our results show that from 2000 the first records of other FTs in EU countries appeared. When the importation peak that starts in 2016 is compared with species records, a lag of two years is evident before records start increasing exponentially in 2019. Normally, turtles are introduced in the wild by intentional release, when they get too big, too old, or too expensive to keep, or they can also escape from captivity (Stringham and Lockwood 2018; Banha et al. 2019). In pet shops several turtle species are available, but they are all small in size (Stringham and Lockwood 2018). For instance, the Chinese pond turtle *Mauremys reevesii*, a commonly traded species, can grow from 5.5 g to 90 g in 200 days (Li et al. 2023). So, when purchased, the small-sized turtles do not need much space or require much expense to keep, but they grow quickly. Thus, the gap between purchase and potential release often corresponds to the turtle's growth period – typically just a few years – until it becomes too large for its owners to manage, depending on the species and the owner's circumstances. Actually, our results suggest that other freshwater turtle imports are the only variable that explain other freshwater turtle records. This aligns with several studies that have found that commercial success is an important driver of species introduction (e.g. Gippet and Bertelsmeier 2021). Since the imports of other FTs are increasing, it is plausible to assume that the same will happen to the records of the same species in the wild. An increase in other FT records has also been described in response to national laws that prohibited the trade of *T. scripta* (Maceda-Veiga et al. 2019). These national laws led to an increase in records of *Pseudemys nelsoni*, *Pseudemys concinna*, and *Graptemys kohni*, in urban lakes in Barcelona (Maceda-Veiga et al. 2019). This pattern also seems to have occurred with the implementation of regulation 1141/2016, which led to a European increase in other FTs' records, particularly *Graptemys pseudogeographica*, *Pseudemys concinna* and *Chelydra serpetina.*

When we compare the number of imports with the records of specific species, we identify that some of the most traded species are also the ones with the most records. This supports the fact that highly traded species are the ones with higher invasion risk (Stringham and Lockwood 2018; Gippet and Bertelsmeier 2021). So not only did the implementation of regulation 1141/2016 did not prevent *T. scripta* from spreading, but it also led to the introduction of additional freshwater turtles. These new species add other threats, like hybridization (Rato et al. 2024a), different from the ones posed by *T. scripta*. Many legislative tools focused on invasive species, only address already established species, and do not account for potential

invasive species already available on the market (Maceda-Veiga et al. 2019). There is some exception to this, such as the cases of the Portuguese and the Spanish national laws (Decreto-Lei n.º 92/2019, 2019; Real Decreto 216/2019, 2019).

Whitelists of species that are allowed to be traded may not reduce the risk of release into the wild (Maceda-Veiga et al. 2019; Rato et al. 2024a). To be effective, a whitelist should only incorporate species after a risk analysis, to ensure that traded species do not have significant impacts (Simberloff 2006). For Europe, *Pelomedusa subrufa*, *Chelydra serpentina*, *Apalone mutica*, and *Apalone spinifera* have been assessed, having a serious invasion risk, and *T. scripta* having a moderate invasion risk (Kopecký et al. 2013). However, this is not consistent with our results regarding both *T. scripta* and other FT records. Kopecký et al. (2013) only used import data from Czechia to define the species to use for all Europe and did not incorporate a proxy of propagule pressure, which is important in the success of invasions (Lockwood et al. 2009). The use of blacklists, whitelists, and graylists (lists of species that should have their impacts assessed) will only work if applied together and with flexibility to add or exclude certain species, when more information is obtained (Simberloff and Rejmánek 2011).

In the EU before both the previously cited regulations, there was no common approach to the invasive species problem. There were some legal instruments that also included invasive species, but did not predict a way to reduce its impacts and its release, nor did they predict any eradication, control, or surveillance strategy (Shine et al. 2010). However, the existing regulations are not enough to combat established invasive species or to stop their introduction. A major problem is that the regulated species already have established populations, which makes them difficult to control and eradicate. The list of Invasive Alien Species of Union Concern is only the basis from which member states must work on to develop their own lists. However, the problem is that there are normally large differences on which species are in each member state's national legislation and even different years of the implementation of these national lists (Shine et al. 2010). For instance, in Portugal all species of the *Graptemys* genus are prohibited, but in Spain these species are not listed and can be bought and moved into Portugal (Decreto-Lei n.o. 92/2019, 2019; Real Decreto 216/2019, 2019). The creation of one solution that fits all kinds of legislation is not easy due to the diversity of biogeographic and climatic regions within the EU (Shine et al. 2010; Keller et al. 2011). We suggest that, instead of a unified concern list, the EU could develop a concern list for each biogeographic region, but at the same time preventing EU interregional trade of the listed species. Each country would then need to adopt the concern lists that apply to each of their biogeographic regions. Currently, national legislations are not a solution to the FT invasions' problem because, despite banning the trade of several species, new species appear to substitute the old ones (Rato et al. 2024a). Different solutions, such as a horizon scanning approach similar to the one of Oficialdegui et al. (2023), are needed to identify which traded species are likely to be introduced when other species trade is banned.

Despite all of the constraints of the CITES database and GBIF records, our results clearly demonstrate that the current EU legislation to prevent and combat invasive species, has not been effective for freshwater turtles. This calls for other actions, like eradication and control programs to stop their spread and decrease their numbers. These efforts are compulsory for EU members and EU-listed species, in the scope of the present regulation. However, this study found no evidence of a decline in

T. scripta records in the wild. Moreover, EU legislation may have unintentionally contributed to an increase in imports and records of other freshwater turtle species. Rather than effectively addressing the issue, these regulations may have inadvertently facilitated the introduction of alternative freshwater turtles by shifting trade patterns.

Acknowledgments

The authors thank the editor, Tammy Robinson-Smythe, and two reviewers, Ana Nunes and an anonymous one, for their helpful comments and suggestions which greatly improved the manuscript.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Funding

This study had the support of FCT through the strategic project UIDB/04292/2020 awarded to MARE and through project LA/P/0069/2020 granted to the Associated Laboratory ARNET. Filipe Banha is supported by the Foundation for Science and Technology through an individual contract (CEEC/01896/2021). João Rato holds a Ph.D. grant from Foundation for Science and Technology (2024.01395.BD).

Author contributions

Conceptualization: JR, PB, FB. Data curation: PB, JR. Formal analysis: JR, PB. Supervision: FB, MG, PA. Validation: MG, PA, FB. Visualization: PB, JR. Writing – original draft: JR. Writing – review and editing: PB, MG, FB, PA.

Author ORCIDs

João Rato https://orcid.org/0000-0002-7270-3501
Pedro Brandão https://orcid.org/0009-0008-9911-0272
Mafalda Gama https://orcid.org/0000-0001-8682-1923
Filipe Banha https://orcid.org/0000-0002-7963-3497
Pedro Anastácio https://orcid.org/0000-0003-1808-3847

Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

References

Azevedo A, Guimarães L, Ferraz J, Whiting M, Magalhães-Sant'Ana M (2021) Pet reptiles – are we meeting their needs? Animals (Basel) 11: 2964. https://doi.org/10.3390/ani11102964

Banha F, Gama M, Anastácio PM (2017) The effect of reproductive occurrences and human descriptors on invasive pet distribution modelling: *Trachemys scripta elegans* in the Iberian Peninsula. Ecological Modelling 360: 45–52. https://doi.org/10.1016/j.ecolmodel.2017.06.026

Banha F, Diniz A, Anastácio PM (2019) Patterns and drivers of aquarium pet discharge in the wild. Ecological Indicators 106: 105513. https://doi.org/10.1016/j.ecolind.2019.105513

Basler C, Bottichio L, Higa J, Prado B, Wong M, Bosch S (2015) Multistate outbreak of human *Salmonella* poona infections associated with pet turtle exposure – United States, 2014. Morbidity and Mortality Weekly Report 64: 804. https://doi.org/10.15585/mmwr.mm6429a7

Bates D, Mächler M, Bolker B, Walker S (2015) Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67(1): 1–48. https://doi.org/10.18637/jss.v067.i01

Bonacina E, Oltolina M, Robbiati R, Pinzauti P, Ebani VV (2021) Serological survey on the occurrence of anti-*Leptospira* spp. antibodies in red-eared terrapins (*Trachemys scripta elegans*) Living in a Natural Park of Northern Italy. Animals (Basel) 11: 602. https://doi.org/10.3390/ani11030602

Bush ER, Baker SE, Macdonald DW (2014) Global trade in exotic pets 2006–2012: Exotic pet trade. Conservation Biology 28: 663–676. https://doi.org/10.1111/cobi.12240

CITES (2025) Appendices I, II and III. Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Colautti RI, MacIsaac HJ (2004) A neutral terminology to define 'invasive' species. Diversity & Distributions 10: 135–141. https://doi.org/10.1111/j.1366-9516.2004.00061.x

Costa ZJ (2014) Responses to predators differ between native and invasive freshwater turtles: Environmental context and its implications for competition. Ethology 120: 633–640. https://doi.org/10.1111/eth.12235

Real Decreto 216/2019 (2019), de 29 de marzo, por el que se aprueba la lista de especies exóticas invasoras preocupantes para la región ultraperiférica de las islas Canarias y por el que se modifica el Real Decreto 630/2013, de 2 de agosto, por el que se regula el Catálogo español de especies exóticas invasoras, Ministerio para la Transición Ecológica.

Decreto-Lei n.º 92/2019 (2019) Diário da República (Presidência do Conselho de Ministros), 3428–3442.

Easter T, Trautmann J, Gore M, Carter N (2023) Media portrayal of the illegal trade in wildlife: The case of turtles in the US and implications for conservation. People and Nature 5: 758–773. https://doi.org/10.1002/pan3.10448

European Environment Agency (2012) The impacts of invasive alien species in Europe. Publications Office, LU. https://data.europa.eu/doi/10.2800/65864 [November 13, 2023]

Evans T, Zu Ermgassen P, Amano T, Peh KS-H (2018) Does governance play a role in the distribution of invasive alien species? Ecology and Evolution 8: 1984–1994. https://doi.org/10.1002/ece3.3744

Fielding AH, Haworth PF (1995) Testing the generality of bird-habitat models. Conservation Biology 9: 1466–1481. https://doi.org/10.1046/j.1523-1739.1995.09061466.x

García-Díaz P, Ross JV, Woolnough AP, Cassey P (2017) The illegal wildlife trade is a likely source of alien species. Conservation letters 10: 690–698. https://doi.org/10.1111/conl.12301

Gippet JMW, Bertelsmeier C (2021) Invasiveness is linked to greater commercial success in the global pet trade. Proceedings of the National Academy of Sciences of the United States of America 118: e2016337118. https://doi.org/10.1073/pnas.2016337118

Ivanova NV, Shashkov MP (2021) The possibilities of GBIF data use in ecological research. Russian Journal of Ecology 52: 1–8. https://doi.org/10.1134/S1067413621010069

Johnson BA, Mader AD, Dasgupta R, Kumar P (2020) Citizen science and invasive alien species: An analysis of citizen science initiatives using information and communications technology (ICT) to collect invasive alien species observations. Global Ecology and Conservation 21: e00812. https://doi.org/10.1016/j.gecco.2019.e00812

Keller RP, Geist J, Jeschke JM, Kühn I (2011) Invasive species in Europe: Ecology, status, and policy. Environmental Sciences Europe 23: 23. https://doi.org/10.1186/2190-4715-23-23

Kopecký O, Kalous L, Patoka J (2013) Establishment risk from pet-trade freshwater turtles in the European Union. Knowledge and Management of Aquatic Ecosystems 02. https://doi.org/10.1051/kmae/2013057

Kopecký O, Bílková A, Hamatová V, Kňazovická D, Konrádová L, Kunzová B, Slaměníková J, Slanina O, Šmídová T, Zemancová T (2019) Potential invasion risk of pet traded lizards, snakes, crocodiles, and tuatara in the EU on the basis of a Risk Assessment Model (RAM) and Aquatic Species Invasiveness Screening Kit (AS-ISK). Diversity 11: 164. https://doi.org/10.3390/d11090164

Larson ER, Graham BM, Achury R, Coon JJ, Daniels MK, Gambrell DK, Jonasen KL, King GD, LaRacuente N, Perrin-Stowe TI, Reed EM, Rice CJ, Ruzi SA, Thairu MW, Wilson JC, Suarez AV (2020) From eDNA to citizen science: Emerging tools for the early detection of invasive species. Frontiers in Ecology and the Environment 18: 194–202. https://doi.org/10.1002/fee.2162

Li H, Guo J, Zhao J, Ye Z, Ji M, Zhu S (2023) Effects of lighting mode on the growth performance, cortisol level and oxidative stress of juvenile Chinese three-keeled pond turtle (*Chinemys reevesii*). International Journal of Agricultural and Biological Engineering 16: 58–62. https://doi.org/10.25165/j.ijabe.20231604.7656

Liuzzo M, Termine R, Marrone F (2020) First evidence of an egg-laying attempt of feral *Trachemys scripta* (Schoepff, 1792) in Sicily (Lake Pergusa, Italy).

Lockwood JL, Cassey P, Blackburn TM (2009) The more you introduce the more you get: The role of colonization pressure and propagule pressure in invasion ecology. Diversity & Distributions 15: 904–910. https://doi.org/10.1111/j.1472-4642.2009.00594.x

Lockwood JL, Welbourne DJ, Romagosa CM, Cassey P, Mandrak NE, Strecker A, Leung B, Stringham OC, Udell B, Episcopio-Sturgeon DJ, Tlusty MF, Sinclair J, Springborn MR, Pienaar EF, Rhyne AL, Keller R (2019) When pets become pests: The role of the exotic pet trade in producing invasive vertebrate animals. Frontiers in Ecology and the Environment 17: 323–330. https://doi.org/10.1002/fee.2059

Macdonald DW, Harrington LA, Moorhouse TP, D'Cruze N (2021) Trading animal lives: Ten tricky issues on the road to protecting commodified wild animals. Bioscience 71: 846–860. https://doi.org/10.1093/biosci/biab035

Maceda-Veiga A, Escribano-Alacid J, Martínez-Silvestre A, Verdaguer I, Mac Nally R (2019) What's next? The release of exotic pets continues virtually unabated 7 years after enforcement of new legislation for managing invasive species. Biological Invasions 21: 2933–2947. https://doi.org/10.1007/s10530-019-02023-8

Millington M, Holmes B, Balcombe S (2022) Systematic review of the Australian freshwater ornamental fish industry: The need for direct industry monitoring. Management of Biological Invasions: International Journal of Applied Research on Biological Invasions 13: 406–434. https://doi.org/10.3391/mbi.2022.13.2.09

Mitura A, Niemczuk K, Zaręba K, Zając M, Laroucau K, Szymańska-Czerwińska M (2017) Free-living and captive turtles and tortoises as carriers of new *Chlamydia* spp. PLoS One 12: e0185407. https://doi.org/10.1371/journal.pone.0185407

Nori J, Tessarolo G, Ficetola F, Loyola R, Di Cola V, Leynaud G (2017) Buying environmental problems: The invasive potential of imported freshwater turtles in Argentina. Aquatic Conservation 27: 685–691. https://doi.org/10.1002/aqc.2715

Oficialdegui FJ, Zamora-Marín JM, Guareschi S, Anastácio PM, García-Murillo P, Ribeiro F, Miranda R, Cobo F, Gallardo B, García-Berthou E, Boix D, Arias A, Cuesta JA, Medina L, Almeida D, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Casals F, Clavero M, Encarnação J, Fernández-Delgado C, Franco J, Guillén A, Hermoso V, Machordom A, Martelo J, Mellado-Díaz A, Morcillo F, Oscoz J, Perdices A, Pou-Rovira Q, Rodríguez-Merino A, Ros M, Ruiz-Navarro A, Sánchez MI, Sánchez-Fernández D, Sánchez-González

JR, Sánchez-Gullón E, Teodósio MA, Torralva M, Vieira-Lanero R, Oliva-Paterna FJ (2023) A horizon scan exercise for aquatic invasive alien species in Iberian inland waters. The Science of the Total Environment 869: 161798. https://doi.org/10.1016/j.scitotenv.2023.161798

Perez-Santigosa N, Diaz-Paniagua C, Hidalgo-Vila J (2008) The reproductive ecology of exotic *Trachemys scripta elegans* in an invaded area of southern Europe. https://doi.org/10.1002/aqc.974

Pérez-Santigosa N, Díaz-Paniagua C, Hidalgo-Vila J, Florencio M (2011) Does the exotic invader turtle, *Trachemys scripta elegans*, compete for food with coexisting native turtles? Amphibia-Reptilia 32: 167–175. https://doi.org/10.1163/017353710X552795

Pienaar EF, Sturgeon DJE (2024) Exotic pet owners' preferences for different ectothermic taxa are based on species traits and purchase prices in the United States. NeoBiota 91: 1–27. https://doi.org/10.3897/neobiota.91.109403

Polo-Cavia N, López P, Martín J (2014) Interference competition between native Iberian turtles and the exotic *Trachemys scripta*. Basic & Applied Herpetology. https://doi.org/10.11160/bah.13014

Posit team (2022) RStudio: Integrated Development Environment for R (1.1.463). Posit Software, PBC.

Rato J, Brandão P, Anastácio PM, Banha F (2024a) First records of *Mauremys sinensis* in Portugal: A consequence of inadequate policies applied to the exotic pet market. Aquatic Ecology 58: 1091–1096. https://doi.org/10.1007/s10452-024-10125-2

Rato J, Xavier R, Harris DJ, Banha F, Anastácio P (2024b) A comprehensive review of disease-causing agents in freshwater turtles: Implications for conservation and public health. Diversity 16: 171. https://doi.org/10.3390/d16030171

Semenov DV (2010) Slider turtle, *Trachemys scripta elegans*, as invasion threat (Reptilia; Testudines). Russian Journal of Biological Invasions 1: 296–300. https://doi.org/10.1134/S2075111710040077

Shine C, Kettunen M, Genoves P, Essl F, Gollasch S, Rabitsch W, Scalera R, Starfinger U, Brink P (2010) Assessment to support continued development of the EU Strategy to combat invasive alien species. Brussels, Belgium.

Simberloff D (2006) Risk assessments, blacklists, and white lists for introduced species: Are predictions good enough to be useful? Agricultural and Resource Economics Review 35: 1–10. https://doi.org/10.1017/S1068280500010005

Simberloff D, Rejmánek M [Eds] (2011) Encyclopedia of Biological Invasions. University of California Press, Berkeley, 765 pp.

Stringham OC, Lockwood JL (2018) Pet problems: Biological and economic factors that influence the release of alien reptiles and amphibians by pet owners. Journal of Applied Ecology 55: 2632–2640. https://doi.org/10.1111/1365-2664.13237

Sung Y-H, Lee W-H, Leung FK-W, Fong JJ (2021) Prevalence of illegal turtle trade on social media and implications for wildlife trade monitoring. Biological Conservation 261: 109245. https://doi.org/10.1016/j.biocon.2021.109245

Thiele J, Markussen B (2012) Potential of GLMM in modelling invasive spread. CAB Reviews: Perspectives in Agriculture, Veterinary Science, Nutrition and Natural Resources 7(016): 1–10. https://doi.org/10.1079/PAVSNNR20127016

Vrieze SI (2012) Model selection and psychological theory: A discussion of the differences between the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). Psychological Methods 17(2): 228–243. https://doi.org/10.1037/a0027127

Wickham H (2016) ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, New York. https://doi.org/10.1007/978-3-319-24277-4_9

Wood SN (2011) Fast stable restricted maximum likelihood and marginal likelihood estimation of semiparametric generalized linear models. Journal of the Royal Statistical Society. Series B, Statistical Methodology 73: 3–36. https://doi.org/10.1111/j.1467-9868.2010.00749.x

Zamora-Marín JM, Ruiz-Navarro A, Oficialdegui FJ, Anastácio PM, Miranda R, García-Murillo P, Cobo F, Ribeiro F, Gallardo B, García-Berthou E, Boix D, Medina L, Morcillo F, Oscoz J, Guillén A, Herrero-Reyes AA, Aguiar FC, Almeida D, Arias A, Ayres C, Banha F, Barca S, Biurrun I, Cabezas MP, Calero S, Campos JA, Capdevila-Argüelles L, Capinha C, Carapeto A, Casals F, Chainho P, Cirujano S, Clavero M, Cuesta JA, Deltoro V, Encarnação J, Fernández-Delgado C, Franco J, García-Meseguer AJ, Guareschi S, Guerrero-Gómez A, Hermoso V, López-Cañizares C, López-Soriano J, Machordom A, Martelo J, Mellado-Díaz A, Moreno JC, Olivo Del Amo R, Otero JC, Perdices A, Pou-Rovira Q, Quiñonero-Salgado S, Rodríguez-Merino A, Ros M, Sánchez-Gullón E, Sánchez MI, Sánchez-Fernández D, Sánchez-González JR, Soriano O, Teodósio MA, Torralva M, Vieira-Lanero R, Zamora-López A, Oliva-Paterna FJ (2023) A multi-taxa assessment of aquatic non-indigenous species introduced into Iberian freshwater and transitional waters. NeoBiota 89: 17–44. https://doi.org/10.3897/neobiota.89.105994

Supplementary material 1

Supplementary figures S1–S4 and tables S1, S2

Authors: João Rato, Pedro Brandão, Mafalda Gama, Filipe Banha, Pedro Anastácio

Data type: pdf

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/neobiota.102.143330.suppl1

Supplementary material 2

Tukey test results

Authors: João Rato, Pedro Brandão, Mafalda Gama, Filipe Banha, Pedro Anastácio

Data type: xlsx

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/neobiota.102.143330.suppl2

Supplementary material 3

Supplementary data note

Authors: João Rato, Pedro Brandão, Mafalda Gama, Filipe Banha, Pedro Anastácio

Data type: pdf

Copyright notice: This dataset is made available under the Open Database License (http://opendatacommons.org/licenses/odbl/1.0/). The Open Database License (ODbL) is a license agreement intended to allow users to freely share, modify, and use this Dataset while maintaining this same freedom for others, provided that the original source and author(s) are credited.

Link: https://doi.org/10.3897/neobiota.102.143330.suppl3